HYDROGEOLOGIC STUDY
McGRAW-EDISON FACILITY
ALBION, MICHIGAN

PREPARED FOR

McGRAW-EDISON COMPANY
1701 GOLF ROAD
ROLLING MEADOWS, ILLINOIS

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VOL. I

I N D E X

PAGE NUMBER

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PAGE NUMBER

GEOLOGY IN THE AREA OF ALBION, MICHIGAN

LOCATION

The purpose of this section of the report is to provide a geologic background for a discussion of ground water characteristics. It concerns a site in Calhoun County in South Central Michigan. The following paragraphs will present a description of the physiography of the area and an explanation of the surficial geology. A discussion of the subsurface geology will follow including some detail on the geologic units that are important to the groundwater hydrology.

Specifically, the area of concern consists of approximately 16 square miles centered around the town of Albion. This area entails most of the south half of T2S, R4W, and the north half of T3S, R4W. The actual site of the groundwater investigation lies in a small industrial area on the east side of town. Industries surround the site on west, north, and east, and there is a residential area on the south side of the site.

PHYSIOGRAPHY

The area under study has two distinct physiographic divisions. There is an upland area marked by irregular rolling terrain lying along both sides of the Kalamazoo River Valley. The physiographic features that make up the surface landscape are the result of two natural processes.

The first of these is the deposition of hundreds of feet of material from a massive sheet of ice that covered most of the midwestern United States many thousands of years ago. The second of these processes began during the melting period of this continental glacier, and continues to the present day. The ability of moving water to erode and transport the surface deposits has created the landscape that exists today. The historical sequence of these processes will be discussed later in this section of the report.

The upland area, which runs in an east-west belt across the north and south third of the subject area, is the result of glacial deposition. It is part of a larger ridge shaped feature that runs across the central part of Calhoun County. The feature is called a moraine and is formed from accumulated material deposited along the front of a stationary melting ice sheet. At the eastern end of the county, the moraine loses its form as a continuous ridge and separates into a series of smaller isolated areas of upland terrain. These smaller areas are bounded by either the Kalamazoo River or one of the creeks that flow along the eastern boundary of Calhoun County. The subject area of this section of the report covers portions of two of these smaller upland segments of moraine.

The irregular relief of the moraine surface is due to a combination of differential amounts of deposition and the formation of kettle depressions. Kettles form when broken blocks of ice, which have become buried in the glacial debris, melt and the ground surface subsides into the resulting void space. Those sites commonly develop the small lakes or swamps which are frequently found in morainal areas. Such features are prevalent in the Albion area.

Running across the center of the area is the Kalamazoo River Valley. The main branch of the Kalamazoo River is formed in the Albion area where the north and south branches of the river have their confluence. The north branch enters the area at the northeast corner while the south branch flows up from the southwest corner. They join in the southeast corner of the town of Albion. The main river flows westward ultimately to Lake Michigan. Because of the two branches the valley is "Y" shaped with the north branch being the stem of the "Y".

The valley itself is quite shallow with a small floodplain and therefore very little surface expression. This is particularly true of the main river valley and that of the north branch. Surface relief along these two streams is no more than 10 feet. The valley of the south branch is narrower with slightly more noticeable relief. The valley walls of the south branch rise 30 to 50 feet above the level of the stream. The amount of relief along the river changes dramatically further west in the county near the town of Battle Creek. Here, Battle Creek joins the Kalamazoo River and during glacial times the creek carried a much larger size stream than it does at present day. The larger volume of water carved a larger valley along the creek as well as along the Kalamazoo River west of the Battle Creek confluence.

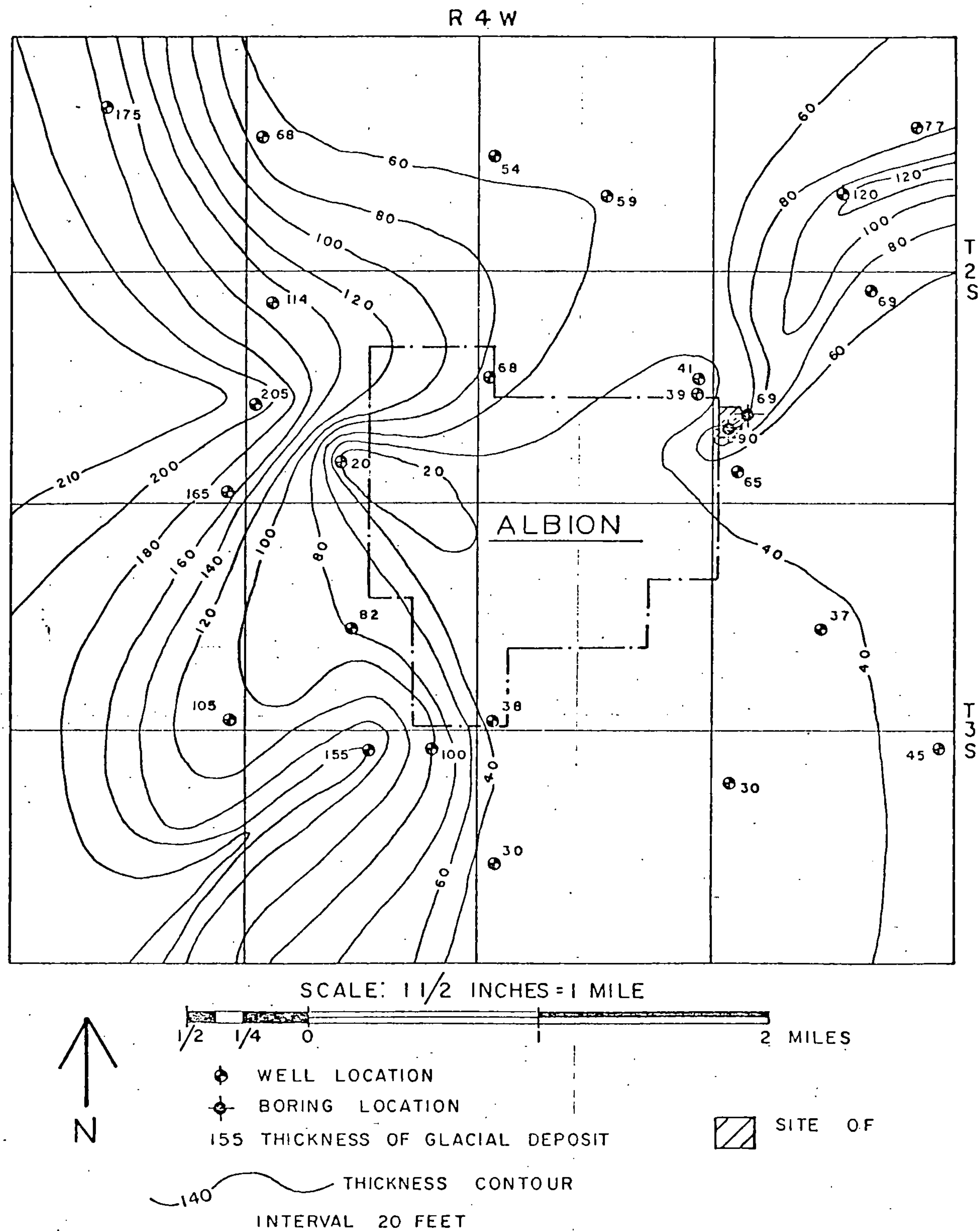
Although the change in elevation along the river valley is slight, the maximum relief across the area is as much as 100 feet. The point of highest elevation is 1050 feet above sea level in the morainal area to the north and south. The gradient drops to a low point of 947 feet along the south branch of the river. Although the maximum change in gradient is largely due to a drop in elevation along the river, the normal gradient over any given portion of the area is only about 40 feet. The thickness of glacial deposits are shown on the following page.

SURFICIAL GEOLOGY

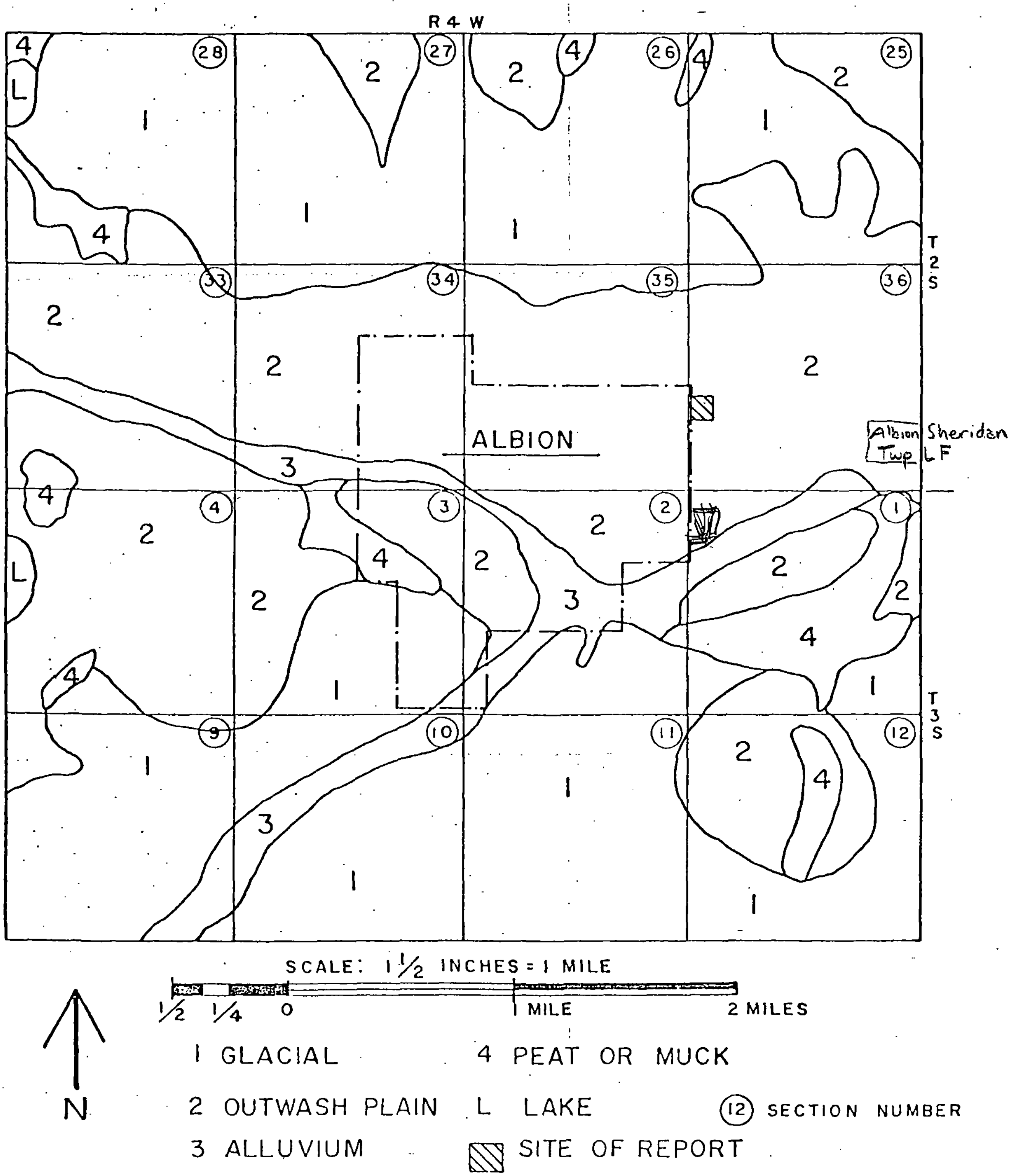
The surficial deposits constitute all of the unconsolidated material that overlies the bedrock. For the subject area this section of the report is considering, they range in thickness from 20 feet to 205 feet. Included with this report is a map showing the thickness of the surficial deposits across the report area. As the map indicates, the greatest thickness of deposits occurs in Section 34 as part of a small valley sloping gently to the west. There are also thick deposits in the southwest corner and northeast corner in similar small valleys. The deposits are thinnest along a north-south ridge running through the east half of the area. Across the actual site of investigation, the thickness ranges from 41 to 90 feet.

The character of the surface deposits basically consists of three types of materials. There is a generally clayey material called Till, granular deposits composed mainly of sand and gravel referred to as Outwash or Alluvium, and an organic substance called Peat or Muck. A map of the surficial geology, presented on page 5, has been prepared showing relative locations of these deposits. The map is based on data from parent materials of various soil types as well as logs of representative water wells and soil borings. The boundaries are generalized in some places and should not be used to delineate specific areas.

THICKNESS OF GLACIAL DEPOSITS



SURFICIAL GEOLOGY



Till is a poorly sorted unstratified material deposited directly from melting ice. In the mapped area, till is found in the moraines running across the north and south third of the map and labeled as Area 1. It is a sandy clay with a little gravel. The Till deposits along the north side of the area are quite thick and continuous. Those along the south side of the area are extensive at the surface but thin to the west at depth. The Till can also be found as a continuous layer along the east side of the area underlying the sand and gravel deposits.

Outwash is a stratified water-deposited material that commonly occurs as a widespread sheetlike deposit that blankets the surface of the till plain in front of a moraine. This results when drainage from the melting ice flows out across the till plain depositing the material it carries. Such deposits are called Outwash Plains. The surface of outwash plains are normally smooth and decrease slightly in elevation going away from the front of the moraine. They may have some kettle depressions. Meltwater streams at this point commonly have a high volume flow at a high velocity. This keeps the fine grain size particles in suspension leaving outwash deposits composed predominantly of sands and gravels. Quite frequently meltwater becomes channeled through existing stream valleys where outwash is then deposited with the coarser grain sizes the furthest away from the river. These valley deposits of outwash tend to be better sorted than those in the outwash plains.

The outwash deposits in the subject area can be found in an east-west trending outwash plain that crosses the central one-third of the map. On the surficial geology map, the outwash deposits are labeled as Area 2. The outwash plain is approximately one to one-and-a-half miles in width and is a small extension of a much larger outwash plain to the west. The outwash deposits are very thick at the southwest corner and thin to the east where they overlie the till. With depth, the outwash deposits become more extensive; increasing in size at the southeast and northwest corners of the area.

Alluvium is also a granular material that is water deposited. It is commonly found within the stream bed and floodplain of an existing river. Unlike outwash, alluvium is deposited in response to volumes and rates of flow near the daily average. Therefore alluvium is found to consist of the finer grained materials of silt and sand. It is a well-sorted and stratified deposit. Commonly the sorting and stratification are better than in the outwash deposits. Alluvium is mapped as Area 3 along the Kalamazoo River.

The Peat and Muck deposits, which occur at scattered locations across the map, form in the depressions and topographically low areas left in the glacial deposits. A few areas of organic materials also form in low, backwater portions of the Kalamazoo River Valley. Such depressed areas frequently become lakes or swamps that stagnate due to inefficient drainage and develop heavy vegetation growth. Dead and decaying organic matter begins to accumulate in this type of environment along with local slopewash deposits of sand, silt, and clay. Peat is composed almost totally of decayed and partially decayed vegetation. Muck is composed of older, more finely disintegrated organic matter mixed with silt and clay. Muck is a denser material than Peat, although both are highly compressible. The organic deposits are included as Area 4 on the map. Peat and alluvium are not glacially deposited. Their formation began on the post glacial landscape in accompanyment with the development of the drainage system and continues into the present day. Areas on the map marked with an "L" are small lakes that represent depressions that have filled with water.

Also located on the map with a striped pattern is the actual site of the ground water investigation. It lies at the northeast corner of Albion in the area of outwash deposits. The surficial deposits across the site are quite uniform. Virtually all of the soil borings made at the site show fine to coarse grained sand as the surficial material. The outwash deposits exist to an average depth of sixty feet across the site and tend to be thicker to the east and south. There are occasional thin layers of ~~silty or~~ clayey materials interlayered with the sand.

GLACIAL HISTORY

The history of these deposits is told by the repeated passage of the glaciers across what is now the state of Michigan. The first glacial advance began more than one million years ago. Since that time there have been many advances and retreats of the glacial ice with intervening periods of warm climates. These have been grouped into four major cycles of glaciation. Due to the tremendous errosive power of moving glacial ice most of the deposits left from previous ice sheets were removed by the ones that followed. As a result the surficial deposits as well as the surface landscape found in Michigan today are the product of the most recent episode of glaciation. The last glacier to cover the state of Michigan is referred to as the Wisconsinan. It made its initial advance more than 75,000 years ago and finally retreated from the area between 15,000 and 17,000 years ago.

The Wisconsinan ice moved south out of central and eastern Canada over three different routes. Individual lobes of ice moved down the Lake Michigan basin, the basin of Lakes Huron and Erie, and the smaller basin of Saginaw Bay. They all merged at roughly the center of the state to form part of the continental glacier that covered much of the midwest. During its forward movement, the ice scoured and eroded the land surface beneath the glacier and great quantities of boulders, sand, silt, and clay were frozen into the ice. During its retreat, the melting glacier redeposited this material, called drift, over the scoured surface to create the features of the present landscape. It is significant to note that all the surface features in the county are oriented northwest to southeast indicating they were deposited by an ice sheet moving in a northeasterly direction. To achieve this orientation the ice must have been retreating toward the basin of Saginaw Bay; which was the route followed by one lobe of the glacier during its advance. Most likely the retreating glacier followed the same routes it had taken during its advance and the northeasterly moving Saginaw lobe was the parent ice of the surficial geology of Calhoun County. The retreat of the glacier across Calhoun County is believed to have occurred in the following manner. This description is based on information from Roger's and Smith's, "Soil Survey of Calhoun County".

The first part of the county to be free of glacial ice was the southwest corner. Northeasterly movement of the glacier continued steady until just north of the town of Burlington where the glacier paused and left deposits of till and outwash. Further retreat to the northeast brought the front of the ice to a position essentially across the center of the county along the present course of the Kalamazoo River. At this location the glacier was very close to or just north of the town of Albion. Here the glacier again paused and began depositing a narrow moraine along the south side of the Kalamazoo River. Just east of the town of Marshall, the ice underwent some change in its depositional pattern as the moraine at that location ceases to be a continuous ridge and spreads out into a broad rolling plain with numerous lakes and swamps. At the eastern border of Calhoun County this widespread morainal area covered about half of the county including the Albion area. The rolling upland areas to the north and south of Albion are part of this widespread moraine. During formation of this morainal area, the glacier was also depositing outwash that spread out across the area in front of the moraine. Following this pause, the glacier underwent further melting which withdrew the ice front to within five or six miles of the county's northern border before it paused one last time. This pause was most likely of longer duration than the preceding two as it produced a much wider and rougher moraine and laid down the widest, most continuous outwash plain in the county. This outwash plain, which is up to four miles wide in the western half of the county, generally follows the north side of the second moraine which roughly coincides with the course of the Kalamazoo River. When this outwash encountered the smoother topography at the eastern end of the second moraine, it separated into four narrower belts of outwash that followed the existing routes of drainage. The belts branched off to the south towards the St. Joseph's River; to the east along the Kalamazoo River; and to the north along the north and south branches of Rice Creek. The outwash in these belts covered the lower portions of the second moraine. The outwash running across the center of the Albion area, in which the groundwater investigation site actually lies, is the eastern belt deposited along the Kalamazoo River. When movement began once again, the glacier completed its final retreat from Calhoun County leaving a gently rolling till plain across the northeast corner.

BEDROCK GEOLOGY

The bedrock of the state of Michigan consists of approximately 7000 feet of sedimentary rocks overlying a basement complex of igneous and metamorphic rocks. The basement rocks are the oldest and deepest in Michigan and date from the Precambrian Era more than 1 billion years before the present. They originated as igneous rock from both extrusive and intrusive molten material. Several times they underwent uplifting and erosion and were metamorphosed from the extreme heat and pressure of deformation and deep burial.

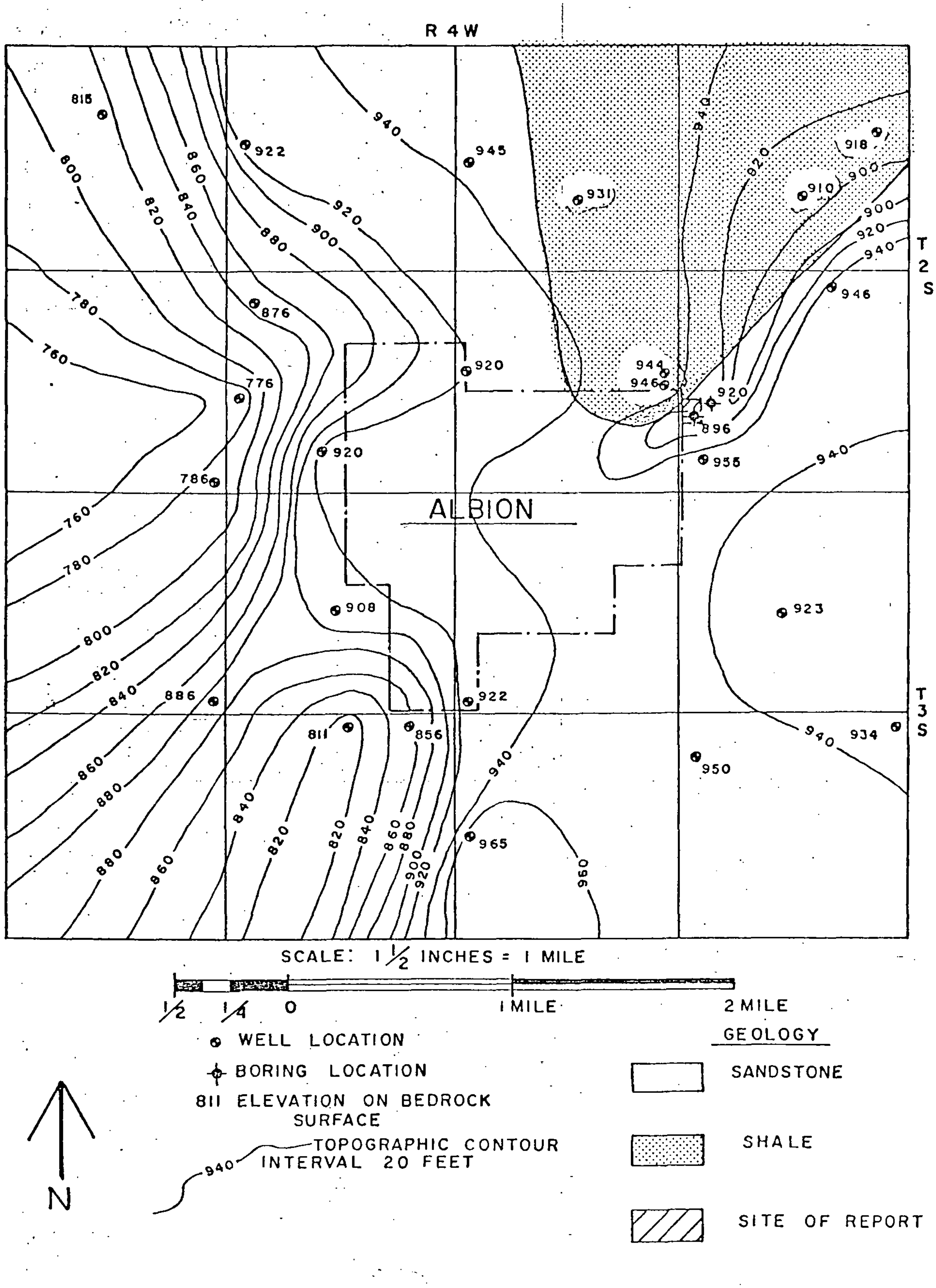
The overlying sedimentary rocks were formed during a cycle of repeated submergence and uplift of the interior of the North American Continent. During times of submergence a shallow inland sea covered the midwestern United States. Materials deposited in the sea accumulated on the bottom, were consolidated by the weight of overlying deposits, and formed the rocks that make up the stratigraphy of Michigan. The sedimentary rocks are all Paleozoic and are detailed on the Michigan Stratigraphic Column included with this report. It was copied from Lilienthal's report of Barry County. As can be seen on the column, the majority of the rocks are limestones and dolomites with a sandstone at the bottom and a few shale units between. The rock types represent changes in the depositional environment of the sea. The sea was not in existence continually during the Paleozoic time but transgressed and regressed in response to uplift and downwarping of the land mass. Sandstones were deposited in shallow water, near shore beach situations; limestones represent a continental shelf area with moderately shallow water where only fine grain particles are still in suspension. These settle to the bottom as layers of mud. Two rock types are unique in the Stratigraphic Column. The Silurian Salina group has many layers of anhydrite and salt deposition and the late Devonian Antrim Shale is highly radioactive. The sedimentary rocks of Michigan range in age from 570 million years before present for the Cambrian rocks immediately above the basement to 330 million years for the Marshall Sandstone which is the surface bedrock unit underlying the glacial deposits over most of the Albion area.

Structurally, the bedrock has been gently depressed toward the center of the state creating a large scale feature referred to as the Michigan Basin. The basin resembles a shallow symmetrical bowl with the youngest rocks at the center and older ones moving away from the center in roughly concentric circles. A geologic map of the state is included to illustrate the structural pattern. Calhoun County sits on the southwest flank of the basin approximately two-thirds of the way from the center.

The majority of the rocks on the bedrock surface beneath the Albion area are Mississippian in age. However, as is indicated on the geologic map, the contact line between the lower Mississippian and lower Pennsylvanian rocks runs directly through the Albion area. This contact was not represented on the enclosed map of bedrock geology and topography because the two different age rocks are similar in composition and, with the limited data available from the well logs, it was not possible to differentiate between them. Some speculation can be made however. The Mississippian and Pennsylvanian rocks are both sandstones at their point of contact, but the Pennsylvanian rocks are sandstones only in the basal layer and grade rapidly upward into shale. A few of the well logs from the northern half of the area do indicate shaley sandstone and there is a small area at the northeast corner where shale is exposed on the bedrock surface. Because it is suggested that Pennsylvanian rocks do exist in the Albion area, these shaley rocks best match the anticipated location for the younger rocks. This is a highly tenuous classification however, because the older Mississippian sandstones also have occasional thin occurrences of interbedded shale.

The Mississippian rocks at the bedrock surface are classified as the Marshall Formation. The Marshall is composed of two sandstone units which are very similar and normally not differentiated. They are the upper Napoleon and the Lower Marshall. The rock is gray, fine to coarse grained, and micaceous with flakes of muscovite and a trace of pyrite. The rock is poorly sorted, moderately cemented, and highly permeable. If Pennsylvanian rocks are found in the area, they belong to the Saginaw Formation. They are white to gray sandstones with interbedded layers of shaley sandstone and shale.

GEOLOGY AND TOPOGRAPHY OF BEDROCK SURFACE



The elevations on the bedrock surface map are calculated from approximate surface elevations and, therefore, vary in accuracy by about 20 feet-high or low. Although the numbers may not be exact, the pattern should be a general representation of the bedrock surface. There is also a narrow steep-walled valley at the northeast corner. This valley runs directly beneath the actual site of this report. The points of data for this map were taken from water well records recorded with the Michigan Department of Natural Resources as well as borings made by Testing Service Corporation at the project site. There are not a sufficient number of well points on the map to depict in detail the surface topography. Because of a particularly sensitive lack of data at the center of the map, it is possible that any of the three valleys could be connected across the center of the map. Their true extent cannot be determined without more data.

GROUNDWATER CHARACTERISTICS

The geologic formations which are of primary significance to the groundwater system are those with good porosity and permeability. To yield a good supply of groundwater, a formation must first of all have adequate void space between the individual grains of rock to hold water. Second, the void spaces must be interconnected so the water will move through the unit. Geologic formations that have these characteristics and yield groundwater are called aquifers.

The primary aquifers in the Albion area are the uppermost formations on the geologic column. Within the overlying glacial drift, the outwash deposits are very good aquifers. The unconsolidated sand and gravel make these deposits highly porous and permeable and they produce fairly large quantities of water. The aquifer potential of the outwash deposits is best developed over the southwest quarter of the Albion area. Here, the bedrock surface drops off into two valleys and thick sequences of sand and gravel have accumulated. Bedrock valleys are frequently good sources of groundwater as the bedrock walls tend to confine the water and allow large quantities to develop as well as influence its movement. The outwash deposits are spread throughout the Albion area; however, as mentioned previously, there is a layer of clay running at varying depths across the eastern half of the area that separates the outwash into thinner isolated areas. The impermeable clay reduces the movement of water throughout the outwash and confines it to the smaller areas. There is also a small bedrock valley at the northeast corner of the area that runs directly under the actual site of this report. The layer of clay also runs through this valley, hovever, and reduces its groundwater potential by excluding water from above. Another factor affecting the performance of an aquifer is its recharge ability. Because the outwash deposits are exposed at the surface, recharge of their water supply from rainfall is easily obtained.

The Marshall sandstone directly beneath the glacial deposits is also an important aquifer. Sandstone may be porous rock with good permeability and can produce a good groundwater yield. The ~~Marshall Formation~~ is up to 200 feet in thickness and together with the glacial outwash produces a reliable aquifer system. ~~The outwash-sandstone aquifer is widely used by many individuals and municipalities for their groundwater supplies. The sandstone aquifer has good access to recharge from surface waters through the glacial drift~~.

There is little information available concerning the aquifer characteristics of the Saginaw Formation. The basal sandstone is probably similar to the Marshall Sandstone in groundwater availability. As the amount of shale increases, the effectiveness of the aquifer is, no doubt, greatly reduced.

The rock unit directly underlying the Marshall Sandstone is the Coldwater Shale. This unit is important to the groundwater system because it is a highly impermeable rock. Although it yields no groundwater, it does confine the water in the outwash-sandstone aquifer system and prevents it from moving into lower rock formations. There are other porous and permeable formations at varying depths throughout the geologic column. Most of the limestone and dolomite units as well as the Cambrian sandstone have groundwater supplies. However, the amount and quality of the water is suspect. There are reports from other areas in Michigan that groundwater below the Coldwater Shale is saline and of poor drinking quality. The cost of drilling to greater depths also reduces its usefulness.

GEOLOGY AND SOILS IN THE VICINITY OF THE McGRAW-EDISON SITE

The preceding discussion of "Geology in the Area of Albion, Michigan" presented a geologic background for a relatively small geographic area (approximately 16 square miles) surrounding the town of Albion. The following discussion presents a description of the subsurface conditions as determined from ~~soil borings made at 45 different station locations on McGraw-Edison, Albion Industries, Airco and Holtz properties~~.

A total of ~~65 monitoring wells were installed~~ for this study (some stations consist of both a shallow and intermediate or deep well). There are ~~41 shallow, 21 intermediate~~ and ~~3 deep monitoring wells~~. The shallow wells were generally installed in the 25 to 45 foot range which penetrated the upper water table approximately 10 feet or less. The intermediate wells were installed generally in the 50 to 100 foot range. These intermediate wells were either installed in an underlying water bearing strata or in some cases were installed in basically the same aquifer as the shallow well but at a greater depth. Some of the intermediate wells penetrated the sandstone bedrock. The 3 deep wells were installed into the sandstone bedrock at depths of 260 to 270 feet below ground surface. These deep wells ended at depths of 175 feet to 235 feet below the top of the sandstone formation.

Soil samples were taken by the Split Spoon method at 5 foot depth intervals until the first saturated materials were encountered. The sampler was driven 24 inches instead of the standard 18 inches, leaving an unsampled interval of only 3 feet between consecutive samples. Below the top of the saturation zone, Split Spoon sampling of the soils was continuous. This sampling procedure was significant in that it presented an accurate and detailed column of the stratigraphy at each station location.

TOPOGRAPHY

The topography of the site, with the exception of the cultivated land on the Holtz property and portions of Airco property, has been modified by man during the development of McGraw and Albion Industries properties. A topographic map with 5 foot contour intervals (prepared from 1953 aerial photograph included with this report, gives a general picture of the current topography. Three special features worthy of mention, which directly affect ground water flow and will be discussed later in this report are:

1) the retention pond on Albion Industries,
2) the fire protection sump on the McGraw property, and
3) the low wet area on Airco property.

STRATIGRAPHY

The thickness of the ~~unconsolidated deposits~~ in this study area, as indicated by soil boring data, ~~ranged from approximately 34 to 88 feet~~. These pleistocene deposits consisted mainly of ~~granular soils~~ deposited as ~~outwash or glaciofluvial material~~. As previously mentioned outwash deposits are stratified materials deposited by flowing water from melting glacial ice.

Other types of glacial materials encountered included till (unstratified material deposited directly by ice characterized by a lack of sorting and a wide range in particle size) and some glaciolacustrine deposits. Glaciolacustrine materials are fine grained soils deposited in quiet glacial lakes. These materials consist typically of laminated silts and clays.

Due to the number of boring logs and numerous soil descriptions shown, a station by station discussion of all soils encountered has not been done because of the relative uniformity of soil conditions. The individual boring logs are included in the Appendix of this report. To facilitate this discussion, 2 stratigraphic cross sections are presented on Sheet 2 of the drawings in the Appendix of this report. The first cross section is basically along a west to east line through the center of the site consisting of Stations 11, 10, 27, 4, 22, 18, 7, 24, 29 and 28. The second cross section is basically along a north to south line near McGraw's west property line and consists of Stations 1, 6, 7, 3 and 41. These 2 routes were selected in an effort to present what was believed to be the best and most useful information concerning the general stratigraphy and water table data.

As both cross sections show, the upper soil stratigraphy consists of sand outwash. Nearly all of this material can be described as clean, well sorted fine to medium grained sand. The lower outwash deposits exhibit more variation in composition. Most of these materials were described as sand, silty sand and mixtures of sand and gravel. As indicated in both cross sections, typically coarser sized materials were found to exist in many of the lower outwash deposits.

At a number of station locations, till was encountered in the middle and lower portions of the soil profile. The till materials were basically described as silty clays and clayey silts, some of which were also described as sandy. These relatively impermeable materials were found to exist as discontinuous layers and isolated lenses rather than as a continuous layer throughout the site. Two relatively large layers of till can be seen on the north-south profile in the vicinity of Stations 1, 6 and 7. These same two layers can also be seen on the west to east profile in the vicinity of Stations 18, 7, 24, 29 and 28.

Glaciolacustrine deposits, which are not shown on either cross section, were encountered at several stations mainly in the southwest portion of the HOLTZ property. These soils were described as laminated silty clays and clayey silts. They were encountered below the upper outwash material at depths ranging from approximately 35 to 40 feet. The material ranged in thickness from 1.3 to 8.5 feet as encountered during drilling and sampling operations. This material is also relatively impermeable and its existence as a discontinuous layer indicates a small scale type of glaciolacustrine environment.

~~Below the unconsolidated deposits~~, ~~sandstone bedrock was encountered at 18 of the 45 station locations~~. A bedrock topography map (Sheet 3) has been prepared indicating the general surface configuration of the bedrock based on the drilling data from 18 stations. The major surface feature, indicated by this map, is a valley or trough-like depression having a NE to SW trend through the center of the McGraw site. The depression rises fairly abruptly near the SW portion of the site. This abrupt rise can also be seen on the W-E cross section from Station 10 to 11. These stations also represent the greatest relief encountered in the bedrock topography (from a low of approximately 896 at Station 10 to a high of approximately 939 at Station 11).

NX ~~rock cores~~ of the top 20 feet of sandstone were taken at Stations 6, 10 and 21. Several core samples were taken to the Geology Department at Michigan Station University and were identified as ~~Marshall Sandstone.~~ The Marshall Sandstone is Mississippian in age. It is generally fine to coarse grained, moderately cemented and considered to be a ~~good aquifer due to its porous and permeable nature.~~ This formation is underlain by the relatively impermeable Coldwater shale.

LABORATORY TESTING (Permeabilities, Grain Sizes and Atterberg Limits)

A total of 22 permeability tests were performed on soil samples. These tests were performed by the variable head method.

The relatively impermeable silty clays showed permeabilities in the order of magnitude of 10^{-8} cm/sec with one sample testing in the 10^{-9} cm/sec range. The slightly less impermeable clayey silts (some were also sandy) showed permeabilities in the order of magnitude of 10^{-7} and 10^{-8} cm/sec. Two samples which were described as a clayey sandy silt and a sandy clay showed test results in the low 10^{-6} cm/sec range. ~~The permeable outwash sands showed permeabilities in the 10^{-4} and 10^{-5} cm/sec range.~~

Permeability tests were also performed on 2 sandstone ~~rock core samples~~. These tests were performed in the triaxial cell without back pressure. These tests were performed using a confining pressure of 28 psi and a water flow pressure of 18 psi. The results showed ~~coefficients of permeabilities of 2.4×10^{-4} and 3.7×10^{-5} cm/sec.~~ The permeability test results are shown on the individual Boring Logs and are also summarized in the Appendix of this report.

Ten Atterberg limits have been performed. Six of these were run on silty clays (one sample was also sandy). The plastic indexes ranged from 9 to 19 with liquid limits ranging from 24 to 39. Three limits were run on clayey sandy silts and one on a clayey silty sand. These materials showed plastic indexes from 0 to 13 with liquid limits from 14 to 26.

Ten grain size analyses have also been performed. The grain size curves and the Atterberg limit data are also included in the Appendix of this report.

GROUND WATER TABLES

~~Both an upper and lower ground water table were found to exist at many stations where both a shallow and intermediate monitoring well have been installed.~~ The ground water table data have been obtained by making measurements in shallow, intermediate and deep monitoring wells. Readings were taken several times throughout the drilling program. A complete set of measurements was taken on all monitoring wells on June 19, 1981. These measurements were used to prepare the Shallow Aquifer and Deep Aquifer Contour Maps (Sheets 4 and 5). A summary of the water level elevations for measurements made to the nearest 0.01 foot on the above and preceding dates is included in the Appendix.

The existence of the relatively impermeable silty clays and clayey silts (some of which are also sandy) are significant in generating an upper and lower table. ~~They should not, however, be considered to represent a continuous aquitard~~ preventing liquid movements to the lower aquifer. As the stratigraphic cross sections show, ~~there are gaps or windows which could allow passage of a liquid into the lower water table~~. It can also be seen that ~~at some locations the upper and lower water tables merge or nearly~~ merge ~~to form one table~~.

A discussion on direction and rate of flow follows later in this report. In general, however, it can be stated that the direction of flow was found to be to the south and southeast.

PROCEDURES

DRILLING

The soil borings were made using a truck-mounted Mobile 80 drill rig and a Central Mine and Equipment 750 all terrain type vehicle.

The bore holes were advanced by continuous hollow-stem auger flight methods. The majority of the deep borings were advanced by rotary methods. Wash water was used with ~~REVERT~~ at some locations in order to prevent sloughing and caving of the hole. Where REVERT was used, upon completion of the boring ~~FAST BREAK was then used to break down the REVERT~~.

After completing each of the borings, the augers, drill pipe, sampling spoons and other related equipment were steam cleaned prior to drilling the next well. Care was taken during the steam cleaning operations to eliminate possible cross contamination resulting from use of the equipment.

SAMPLING

Samples of the underlying soil were taken according to currently recommended American Society for Testing and Materials procedures for Split Spoon sampling of soils. The materials penetrated were logged by visual inspection of the material brought up by the Split Spoon sample devices.

Care was taken in collection of all ground water samples to eliminate any cross contamination, and insure that a sample representative of the aquifer was collected.

Water samples were obtained from some of the Split Spoon samples in the saturated zone. Samples of the water were also obtained inside the hollow-stem auger and inside the installed well. A one inch diameter PVC pipe, approximately 18 inches in length with a steel plug was used in obtaining the water samples. Initially, the second bale was used for the water sample. It was then determined to use the 10th bale of water for testing. After the high concentration of contaminant was noted, a separate baling device was installed for each of the wells to eliminate possible cross contamination.

Some of the deeper wells were installed in the underlying sandstone. At the three deep well locations, we utilized a double-barrel "NX" diamond bit drilling device to obtain samples of the underlying sandstone.

Hand auger borings were made at some locations. Samples were obtained from the screw auger and the soil placed in glass containers with screw type lids for transporting to the laboratory.

The water samples were placed in special glass vials and sealed with a teflon-coated cap. The samples taken from the Split Spoons were placed in glass containers with screw-type lids.

GROUND WATER MEASUREMENTS

Elevations of the ground water levels were made using a Fisher battery operated water level indicator having an accuracy of 0.01 foot. Numerous measurements were made during the study and minor fluctuations of water table for both the upper and lower aquifer were noted. Elevations of the ground water were established from a U. S. Geological Survey monument. Using these elevations from the various wells in both the upper and lower aquifer, ground water contour lines were established. Studies of these contour lines suggested the direction of ground water flow.

WELL INSTALLATION

~~Observation wells consisted of 2 inch PVC casing connected to a 5 foot section of 2 inch outside diameter stainless steel JOHNSON well point.~~ Some of the wells were completed with TIMCO PVC screens. The well point screens had commercial slots ranging in size from 0.006 to 0.01 inch. Threaded couplings were used exclusively to connect casing lengths since the use of glue immediately prior to well installation could induce various organic solvents, which are contained in the glue, into the water sample.

In drilling the shallow wells which terminated in the upper aquifer, samples were obtained by Split Spoon methods with sample intervals no greater than 5 feet. Upon reaching the zone of saturation, continuous Split Spoon samples were then taken to depths sufficient to permit approximately 10 feet penetration into the upper aquifer.

Upon reaching termination depth, the 2 inch PVC pipe connected to the well screen was then lowered into the open hollow-stem hole. The hollow-stem was then removed and the formation allowed to cave into the annular space. The open hole above the water table that did not cave was then backfilled with formation material brought up during drilling. Bentonite pellets were then placed in the hole approximately 15 feet from existing grade. Above the bentonite pellets, native soil was used to backfill the hole to near ground surface. The final three feet of open hole was filled with concrete to prevent surface water from entering the annular space around the well casing. Steel protector pipes were then concreted in place above the PVC pipe. The protector pipes had steel caps, chains and locking devices.

Deep wells were installed at numerous locations adjacent to the shallow wells. At the deep well locations, the hollow-stem auger was drilled to approximate previous depth of the shallow well. Then continuous Split Spoon samples were taken to termination depth of the bore hole.

The 2 inch PVC with a well screen was then installed inside the hollow-stem. Next, approximately 15 feet of hollow-stem was removed from the bore hole and clean pea gravel was packed in the annular space around the well screen. After this had been accomplished, approximately 5 feet of hollow-stem was removed from the bore hole and bentonite pellets were packed into the annular space above the pea gravel. After this has been accomplished the hollow-stem was removed from the bore hole and sand was used to backfill the annular space to approximate ground surface. A similar-type protector pipe was installed on the deep wells as discussed for the shallow wells.

A deep well was installed near the existing diesel well. At this location, rotary methods were used to make the hole down to approximately 80 feet below existing grade. Bentonite was used to keep the bore hole open; however, the bentonite slurry was not recirculated in making the boring. By not recirculating the bentonite, possible cross contamination of the ground water was eliminated. A 4 inch diameter PVC well casing was then installed to approximately 80 feet in depth. Rotary methods were then used to make the hole to approximately 260 feet below existing grade. REVERT was used in making the rotary boring. After completion of the boring, Fast Break was then flushed into the well to break down the REVERT.

The 2 inch PVC with stainless steel well point was then installed in the deep well using similar procedures as outlined above. Tubing having a diameter of approximately 3/4 of an inch was taped to the 2 inch PVC pipe extending to a depth of approximately 80 feet below existing grade. A Portland cement slurry was then pumped into the 3/4 inch plastic tubing in order to seal the interface of the sandstone and upper granular material.

A 6 inch steel protector pipe was then installed above the well using procedures outline above.

Two additional deep wells were installed to depths of approximately 260 feet below existing grade. Similar drilling, sampling and well installation procedures were followed as outlined above.

ABANDONED BORINGS

The initial 5 soil borings drilled on this project were abandoned by pumping a cement bentonite grout into the bore hole. The drill rods were extended to the bottom depth and the slurry was then pumped into the hole.

It was also necessary to abandon 3 of the other holes as a result of this recent investigation. On these aboandoned holes, similar procedures were used to backfill the boring as outlined above.

TESTING

Permeability tests were performed on representative samples taken from the site. Permeability tests were also performed on the underlying sandstone material. Atterberg Limit and grain size tests were performed on representative samples taken from the site. Results of these tests are presented in the Appendix of this report.

Soil and water samples were tested for possible contaminants. Detailed descriptions regarding the test procedures of contaminants are included in the Appendix of this report.

LYSIMETERS

Lysimeters were installed at various locations in the vadose zone--which is that region located between the ground water table and ground surface. This area is often referred to as the zone of aeration or unsaturated zone. These vacuum-pressure devices were used to obtain water samples from the vadose zone. Vacuums were maintained on all of the lysimeters. Some of the devices did not produce sufficient water for testing, however, many of the units did supply an adequate quantity for laboratory testing.

GROUND-WATER FLOW

Ground-water level measurements were made within the 65 monitoring wells installed for this study. The shallow aquifer was defined by 41 wells set in the 25 to 45 foot depth range. The lower aquifer was monitored in 21 intermediate depth wells installed in the 50 to 100 foot depth range. Three wells were drilled to depths in the order of 260 feet.

Elevations were obtained for the top of each of the well casings. The depth-to-water within each well was measured. All measurements were to the nearest 0.01 foot. Water level measurements were made April 15, 1981 for all wells completed as of that date. Additional readings were taken May 13, 1981 on all of the wells completed as of that date. New readings were taken June 19, 1981 after completion of the last well. The June 19, 1981 levels are plotted on the shallow and deep aquifer plan sheets presented in the Appendix of this report. The isopotential or contour lines have been drawn for 2-foor intervals for the shallow aquifer and 1-foot intervals for the deep aquifer.

~~Three ground-water mounds are related directly to both aquifers.~~ The most influential mound is the ~~retention pond located on ALBION INDUSTRIES~~ property, north of McGRAW property. The remaining two consist of the low ~~"swamp" area on AIRCO property northeast of the site and the pit near the firewell on McGRAW property.~~ During the past three (3) years, the fire-well water was pumped into the pit periodically when the well was operated to satisfy insurance requirements. The frequency of pumping has been reduced significantly since plant shut down in late 1980. Initial water table levels taken in October and November, 1980 compared to the more recent levels confirm the influence of this mound on the aquifers.

The ~~influence of these three mounds should be dependent upon runoff of surface water~~, ~~precipitation and frequency of discharge by the fire well.~~ The contours show that ~~ground water flows radially toward the water table depression on the south and the HOLTZ property southeast of McGRAW property.~~

SHALLOW AQUIFER

The contours for the shallow aquifer show that water flows from the retention pond mound in general in a ~~southeasterly direction toward the HOLTZ property~~. Flow is indicated south-west, then easterly and finally toward the south. Also, flow is indicated from the "swamp" area southwesterly and then toward the south. The water table depression in the center-east portion near the south-east McGRAW property corner corresponds approximately to that area where clay layers between the upper and lower aquifers are absent.

DEEP AQUIFER

The contours for the deep aquifer also show that ~~water flows from the retention pond mound in general in a southeasterly direction~~. Flow is indicated south-west toward Franklyn Avenue and Clark Street. Flow is indicated from AIRCO property southwesterly to McGRAW property and then toward the south.

RATE OF FLOW

The rate of ground-water flow in the study area may be influenced to varying degrees by numerous variables consisting of (1) the retention pond on ALBION INDUSTRIES property; (2) the "swamp" area on AIRCO property; (3) the ~~three city wells located approximately 1000 feet north-west of the site;~~ (4) the McGRAW fire-well pumped into the sump periodically; (5) the McGRAW supply well shut down in October 1979; (6) the active BROOKS FOUNDRY, INC. industrial well located a few hundred feet south-east of the HOLTZ property; and (7) the approximate 50 private active wells immediately south of the site.

Coefficient of permeability tests, which measure the hydraulic conductivity, were performed on 22 samples of the soils encountered on the site. The test results are indicated on the boring logs at the respective depths and on a Summary Sheet in the Appendix of this report. The granular soils have coefficients of permeabilities in the 10^{-4} to 10^{-5} cm/sec range. The ~~cohesive soils coefficients range between 10^{-8} to 10^{-9} cm/sec.~~ The clayey silts and clayey sands coefficients range between the granular and cohesive test results. Two (2) coefficient of permeability tests were performed on the sandstone. These coefficients of permeabilities indicate 10^{-4} to 10^{-5} cm/sec rates.

The effective porosity of the granular soils was estimated to be in the order of 30 percent. The hydraulic gradient was computed between numerous wells. Hydraulic gradient values range from 0.08 near the retention pond mound to near zero in the flat area on the HOLTZ property.

Calculations indicate the rate of ground-water flow to range from approximately ~~0.4 feet per day~~ over the retention pond mound, ~~to 0.08 feet~~ per day from the fire well sump easterly toward the southeast McGRAW property corner, to 70×10^{-4} feet per day on the HOLTZ property. These flow rates correspond to values of approximately 150, 30 and 2.5 feet per year respectively.

ON SITE CONTAMINANT DISTRIBUTION

Several hundred water and soil samples were collected and tested for contaminants. Individual test results and test procedures used are presented in the Appendix of this report. It must be kept in mind that very low concentrations of organics were being investigated. The ability to detect parts-per-billion concentrations is a relatively recent development.

The contaminant was found to be trichloroethylene (TCE). No other major chromatographable components were detected in the samples at levels above the background. A representative concentration level of TCE was selected for each of the observations wells. These numbers were used in establishing the contour lines for the contaminant distribution plumes of the shallow and deep aquifer. The ground-water flow patterns are superimposed on the contaminant plumes for the two aquifers.

The contour lines on Sheets 6 and 7 indicate the approximate limits in three levels of magnitude of trichloroethylene concentrations in the shallow and deep aquifers.

SHALLOW AQUIFER

The contaminant distribution of the shallow aquifer is presented on Sheet 6.

DEEP AQUIFER

The contaminant distribution of the deep aquifer is presented on Sheet 7.

INDUSTRIAL WELLS

~~Trichloroethylene was discovered in the two McGRAW industrial wells. Concentrations of TCE found in these two wells were in the range of 70 to 141 ppb.~~ Two observations wells were drilled to depths of approximately 260 feet below grade. Observation well ~~Number 121D~~ was drilled near the fire-well. Initial test results from this observation well were approximately ~~70 ppb on December 30, 1980; however, results in February, April and May, 1981 showed concentrations of 22.5, 17.8, 18.2 and 20.1 ppb~~.

In view of the 70 ppb reading in December, an additional well was installed to the 260 feet depth range. Observation well Number 111D was drilled approximately 500 feet west of 121D. Test results of water taken from this well in March, April and May 1981 indicated levels of 0.45, 1.08, 1.2, 1.03 and less than 0.01 ppb TCE.

LYSIMETER AND SOIL SAMPLES

Numerous soil samples were tested for possible contamination. The specific test results are presented in the Appendix of this report. Because of the volatility of TCE, concentration levels are rapidly lowered upon exposure to air.

In order to obtain additional data, lysimeters were installed in the vadose zone. Water samples from the zone of aeration or unsaturated zone were collected from the lysimeters. The locations where lysimeters were installed are shown on the drawings in the Appendix of this report. The test results are tabulated in the Appendix. Vacuums were maintained on all the lysimeters, however, to date some of the devices have not produced sufficient water for testing.

We have indicated in the table below, the installation depths and other pertinent data regarding each of the lysimeter installations.

LYSIMETER DATA

DATE INSTALLED 1981	LYSIMETER	DEPTH	SOIL DESCRIPTION	BENTONITE SEAL FROM:
4-2	L-1	15'	Light brown fine to medium SAND, moist	7'-8'
4-2	L-2	15'	Brown fine to medium SAND, very moist	7'-8'
4-2	L-3	15'	Light brown fine to medium SAND, very moist	7'-8'
4-3	L-4	15'	Brown fine to medium SAND, moist	7'-8'
4-6	L-5	14½'	Brown fine to medium SAND, moist	6'-8'
4-6	L-6	14½'	Brown fine to medium SAND, trace small gravel, moist	6'-8'
4-6	L-7	14-3/4'	Brown fine to medium SAND, trace small gravel, moist	7'-9'
4-7	L-8	15½'	Brown to dark brown fine to medium SAND, moist	4'-7'
4-7	L-9	24'	Brown fine to medium SAND, little gravel, moist	4'-6'
4-7	L-10	19½'	Light brown fine to medium SAND, moist	6'-8'
4-7	L-11	21½'	Brown fine to coarse SAND, some gravel, moist	6'-9'
4-7	L-12	24'	Brown fine to medium SAND, moist	6'-9'
4-8	L-13	22-3/4'	Brown gravelly fine to medium SAND, moist	5'-8'
4-8	L-14	24'	Brown fine to medium SAND, moist	3'-6'
4-8	L-15	20'	Light brown fine SAND, moist	5'-8'

LYSIMETER DATA
(continued)

DATE INSTALLED 1981	LYSIMETER	DEPTH	SOIL DESCRIPTION	BENTONITE SEAL FROM:
4-8	L-16	20'	Brown fine to medium SAND, moist	3'-6'
4-8	L-17	22'	Brown fine to medium SAND, moist	3'-6'
6-17	L-18	12'	Brown fine to medium SAND, very moist	none
6-17	L-19	12'	Gray clayey silty fine to medium SAND, very moist	none
6-17	L-20	12'	Brown fine to medium SAND, very moist	none
6-17	L-21	12'	Brown fine to medium SAND, very moist	none
6-17	L-22	14'	Brown fine to medium SAND, very moist	none
6-17	L-23	12'	Brown fine to medium SAND, very moist	none
6-17	L-24	12'	Brown fine to medium SAND, very moist	none
6-17	L-25	14'	Brown fine to medium SAND, very moist	none
6-17	L-26	20'	Brown fine to medium SAND, trace gravel, very moist	none
6-17	L-27	23'	Brown fine to medium SAND, trace gravel, very moist	none
6-17	L-28	25'	Brown fine to medium SAND, trace gravel, very moist	none
6-17	L-29	23½'	Brown fine to medium SAND, little gravel, very moist	none
6-18	L-30	16'	Brown fine to medium SAND, trace gravel, very moist	none

LYSIMETER DATA
(continued)

DATE INSTALLED 1981	LYSIMETER	DEPTH	SOIL DESCRIPTION	BENTONITE SEAL FROM:
6-17	L-31	25'	Brown fine to medium SAND, little gravel, very moist	none
6-17	L-32	25'	Brown fine to medium SAND, little gravel, very moist	none
6-18	L-33	25'	Brown fine to medium SAND, trace gravel, very moist	none
6-18	L-34	24'	Brown fine to medium SAND, very moist	none
6-18	L-35	20'	Brown fine to medium SAND, moist	none
6-18	L-36	17'	Brown fine to medium SAND, trace gravel, very moist	none
6-18	L-37	17'	Brown fine to medium SAND, very moist	none
6-18	L-38	16'	Brown fine to medium SAND, trace gravel, very moist	none
6-18	L-39	16'	Brown fine to medium SAND, trace gravel, very moist	none
6-18	L-40	11½'	Brown fine to medium SAND, very moist	none

OFF SITE CONTAMINANT DISTRIBUTION

ALBION INDUSTRIES

The two shallow wells drilled on Albion Industries property, located north of McGRAW-EDISON, indicate levels of TCE ranging from 0.37 to 3.76 ppb. Two soil samples taken in the 12 to 15 depth range indicated test results of 2 and 18 ppb.

The deep well installed at a depth of 265 feet below ground surface had test results of 6.81, 4.94 and 7.65 ppb TCE.

AIRCO

Five shallow wells and two deep wells (to depths up to 88.5 feet below grade) were drilled on AIRCO property located east of McGRAW-EDISON property.

HOLTZ

Nine (9) shallow and six (6) deep wells were drilled on the HOLTZ property located southeast of McGRAW-EDISON. TCE concentrations ranged from <0.01 to 8.29 ppb in the shallow wells and from <0.01 to 120 ppb in the deep wells.

The contaminant distribution of the deep aquifer is presented on Sheet 7. Deep well Numbers 38D, 35D and 43D indicate less than 10 ppb concentrations, however, wells drilled south and east of these (40D and 42D) indicate concentrations of 30 to 100 ppb. All of these wells were drilled during the last phase of the investigation, however, we have a minimum of four (4) test results from each well. Further sampling and testing may revise the concentration plumes toward the south.

Study of Sheet 7 indicates a "possible" off site source near Michigan Avenue. Consideration should be given to further investigate this area to refine the actual limits of the plumes.

SAMPLING OF EXISTING PRIVATE AND PUBLIC WELLS

Water from numerous private and public wells was sampled and tested for trichloroethylene. Specific test results and addresses are presented in the Appendix. An aerial photograph of the area was obtained from a 1971 flight in addition to a topographic map prepared from aerial photography performed March 17, 1953. We have superimposed the contours on the 1971 map. The general area of investigation is shown on Sheet 8 of the Appendix.

Copies of water well logs obtained from Michigan State Department of Public Health, Calhoun County Health Department and private well drillers are presented in the Appendix.

SUMMARY

The data obtained from this study will be used by others in making recommendations for Phase II work.

APPENDIX

a) References
b) Multi-well Diagram
c) Lysimeter Installation Diagram
d) Laboratory Test Data:
    1) Contaminant Test Results and Procedures
    2) Summary of Coefficient of Permeability Test Results
    3) Atterberg Limit Test Results
    4) Grain Size Curves
e) Boring Logs (Volume II)
f) Water Well Logs
g) Local Climatological Data, 1980, Lansing, Michigan
h) Ground Water Elevations
i) National pollution Discharge Elimination System Permit
j) Drawings:
    1) Location Plan
    2) Stratigraphy of McGraw Site
    3) Rock Contour Map
    4) Shallow Aquifer
    5) Deep Aquifer
    6) Contaminant Distribution - Shallow Aquifer
    7) Contaminant Distribution - Deep Aquifer
    8) Aerial Photo with Contours

CONTAMINANT TEST RESULTS AND PROCEDURES

AQUALAB, INC., Streamwood, Illinois tested the majority of the soil and water samples for contaminants. The contaminant was found to be trichloroethylene (TCE). Split samples were cross checked by ENVIRONMENTAL RESEARCH GROUP, INC., Ann Arbor, Michigan, ROCKY MOUNTAIN ANALYTICAL LABORATORY, Arvada, Colorado and ANALYTIC AND BIOLOGICAL LABORATORIES, Garden City, Michigan. Three of the laboratories used the Gas Chromatograph (GC) method to analyze the organics. ROCKY MOUNTAIN LABORATORY used the Gas Chromatograph/Mass Spectrometer (GC/MS) method in testing for Volatile Organics, Base/Neutrals and Acid Extractables. The trichloroethylene was verified by GC/MS to be present in the samples.

Test procedures followed for the analysis for trichloroethylene was Method 501.2 THE ANALYSIS OF TRIHALOMETHANES IN DRINKING WATER BY LIQUID/LIQUID EXTRACTION prepared by U. S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio dated May 15, 1979.

The instrument used by AQUALAB was a Hewlett Packard Model 5833 Gas Chromatograph equipped with an electron capture detector. The samples were run in the external standard mode with integration and calculations being done by the microprocessor.

AQULAB'S Quality Assurance Program included field blanks and reageant blanks. Standard curves were run with each set of samples with a check of the calibration curve being run approximately every ten samples. Samples were run in duplicate approximately 10% of the time for accuracy data. After an unusually high concentration sample was injected, a reageant blank was injected to assure that no cross-contamination or carryover occured.

Analytical reports on three samples analyzed for Volatile Organics, Base/Neutrals, Acid Extractables and heavy metals are presented in the Appendix in addition to specific test results from the observation wells and private wells.

LOCATION	SAMPLE NO.			TRICHLOROETHYLENE (ppb) LABORATORY		DATE SAMPLED	NOTES
	WATER	SOIL	LYSIMETER	AQUALAB	ERG		
101S		S-1		147		10-15-80	27' to 29'
101S	W-1			77.2		10-15-80	Inside HS at 30'
101S	W-2			111		10-15-80	
101S	W-32			144		10-23-80	
101S	W-55			134		10-31-80	
101S	W-75			154		11-07-80	
101S	W-95			164		11-14-80	
101S	W-124			144	160	12-09-80	
101S	W-240			107		3-27-81	
101D		S-9		12		10-23-80	56' to 56.8'
101D	W-29			<0.1		10-23-80	Inside HS at 57'
101D	W-30			<0.1		10-23-80	Inside HS at 60'
101D	W-31			<0.1		10-23-80	
101D	W-56			17.6		10-31-80	
101D	W-76			20.6		11-07-80	
101D	W-96			50.3		11-14-80	
101D	W-126			7.02		12-09-80	
101D	W-231			1.54,1.52		2-18-81	
101D	W-241			1.40		3-27-81	

Water samples were taken inside well except where noted otherwise. Soil samples were taken by Split Spoon method.

LOCATION	SAMPLE NO.			TRICHLOROETHYLENE(ppb) LABORATORY		DATE SAMPLED	NOTES
	WATER	SOIL	LYSIMETER	AQUALAB	ERG		
102S		S-2		30		10-15-80	18' to 20'
102S	W-3			165		10-16-80	
102S	W-33			167		10-24-80	
102S	W-54			151		10-16-80	
102S	W-73			164		11-07-80	
102S	W-86			170		11-14-80	
102S	W-130			105		12-09-80	
102S	W-242			81.5		3-27-81	
102D		S-10		11		10-24-80	31' to 32'
102D	W-65			6		11-05-80	After 20 minutes of bailing
102D	W-74			16.3		11-07-80	
102D	W-87			47.8		11-14-80	
102D	W-131			3.07		12-09-80	
102D	W-204			2.63		12-29-80	
102D	W-243			0.91, 0.92		3-27-81	
103S	W-4			18.3		10-16-80	Inside HS at 38'
103S	W-5			17.3		10-16-80	
103S	W-36			10.7		10-24-80	
103S	W-51			10		10-31-80	
103S	W-68			16.7		11-07-80	
103S	W-137			17.1	11	12-10-80	
103S	W-260			2.99		4-01-81	

Water samples were taken inisde well except where noted otherwise. Soil samples were taken by Split Spoon method.

LOCATION	SAMPLE NO.			TRICHLOROETHYLENE (ppb) LABORATORY		DATE SAMPLED	NOTES
	WATER	SOIL	LYSIMETER	AQUALAB	ERG		
103D	W-45			12.4		10-29-80	Inside HS after 30 min. of bailin
103D	W-64			62.9		11-05-80	After 35 min. of bailing
103D	W-69			66.1,69.2		11-07-80	
103D	W-139			44.8,44.7		12-10-80	
103D	W-261			12.3		4-01-81	

104S		S-15		<1.0		10-28-80	26.5' to 27'
104S	W-43			117		10-28-80	Inside HS at 28'
104S	W-44			165		10-28-80	
104S	W-49			139		10-31-80	
104S	W-142			213		12-10-80	
104S	W-200			120		12-29-80	
104S	W-228			39.5		2-17-81	
104S	W-264			22.1		4-01-81	

104D	W-66			174		11-07-80	
104D	W-104			202		11-24-80	After 45 min. of bailing
104D	W-143			465		12-10-80	
104D	W-201			207		12-29-80	
104D	W-229			26.5		2-18-81	
104D	W-263			149,137		4-01-81	

Water samples were taken inside well except where noted otherwise. Soil samples were taken by Split Spoon method.

LOCATION	SAMPLE NO.			TRICHLOROETHYLENE (ppb) LABORATORY		DATE SAMPLE	NOTES
	WATER	SOIL	LYSIMETER	AQUALAB	ERG		
105S		S-7		<1.0		10-21-80	18' to 20'
105S	W-23			91.8		10-21-80	Inside HS at 20'
105S	W-24			166		10-21-80	
105S	W-59			121		10-31-80	
105S	W-79			124		11-07-80	
105S	W-162			90.8		12-11-80	
105S	W-230			3.52		2-18-81	
105S	W-279			55.4		4-02-81	

105D		S-8		19		10-22-80	33' to 35'
105D	W-25			11.2		10-22-80	Inside HS at 38'
105D	W-27			3		10-22-80	Inside HS after 35 min. of bailin[g]
105D	W-28			3.2		10-23-80	
105D	W-60			4.5		10-31-80	
105D	W-80			11.5		11-07-80	
105D	W-163			4.78	3.6	12-11-80	
105D	W-196			2.33		12-29-81	
105D	W-278			1.31		4-02-81	

Water samples were taken inside well except where noted otherwise. Soil samples were taken by Split Spoon method.

LOCATION	SAMPLE NO.			TRICHLOROETHYLENE (ppb) LABORATORY		DATE SAMPLE	NOTES
	WATER	SOIL	LYSIMETER	AQUALAB	ERG		
106S	W-8			465,476		10-16-80	Inside HS at 22'
106S	W-9			735		10-16-80	
106S	W-35			1340		10-24-80	
106S	W-46			946,937		10-30-80	
106S	W-72			1322		11-07-80	
106S	W-85			5900		11-14-80	
106S	W-127			574	760	12-09-80	
106S	W-238			377		3-26-80	
106D	W-103			40.8		11-24-80	After 45 min. of bailing
106D	W-129			34.0		12-11-80	
106D	W-216			19.3		2-16-81	
106D	W-253			14.9,13.6		4-01-81	
107 S		S-3		15		10-20-80	38' to 40'
107S	W-13			4745		10-20-80	Inside HS at 38'
107S	W-14			1950		10-20-80	
107S	W-52			10,915		10-24-80	
107S	W-70			30,950		11-07-80	
107S	W-99			18,100		11-14-80	2nd bail
107S	W-101			15,500		11-14-80	3rd bail
107S	W-102			13,800		11-14-80	4th bail
107S	W-100			16,600		11-14-80	10th bail
107S	W-107			9,780		11-24-80	
107S	W-134			12,700	25,000	12-10-80	
107S	W-233			17,400		2-18-81	
107S	W-258			14,500		4-01-81	

Water samples were taken inside well except where noted otherwise. Soil sample were taken by Split Spoon method.

LOCATION	SAMPLE NO.			TRICHLOROETHYLENE (ppb) LABORATORY		DATE SAMPLE	NOTES
	WATER	SOIL	LYSIMETER	AQUALAB	ERG		
107D		S-4		24		10-20-80	48' to 50'
107D	W-15			898		10-20-80	Inside HS at 48'
107D	W-16			1576		10-20-80	
107D	W-53			2925		10-31-80	
107D	W-71			6560		11-07-80	
107D	W-97			8590		11-14-80	2nd bail
107D	W-98			6920		11-14-80	10th bail
107D	W-106			3164		11-24-80	
107D	W-136			3750		12-10-80	
107D	W-218			1850		2-16-80	
107D	W-257			2800		4-01-81	
108S	W-6			55.4		10-16-80	Inside HS at 27'
108S	W-7			98.6		10-16-80	
108S	W-34			93.8		10-24-80	
108S	W-50			99.3		10-31-80	
108S	W-67			136		11-07-80	
108S	W-140			174		12-10-80	
108S	W-275			87.1		4-02-81	
108D		S-17		146		11-05-80	40.5' to 41'
108D	W-105			72.5		11-24-80	After 45 min. of bailing
108D	W-141			67.9		12-10-80	
108D	W-262			44.9		4-01-81	

Water samples were taken inside well except where noted otherwise. Soil samples were taken by Split Spoon method.

LOCATION	SAMPLE NO.			TRICHLOROETHYLENE (ppb) LABORATORY		DATE SAMPLE	NOTES
	WATER	SOIL	LYSIMETER	AQUALAB	ERG		
109S	W-47			4.9		10-31-80	Inside HS at 31'
109S	W-48			4.5		10-31-80	
109S		S-16		<0.1		10-31-80	27' to 29'
109S	W-82			9.5		11-07-80	
109S	W-94			36.1		11-14-80	
109S	W-144			4.11		12-10-80	
109S	W-202			2.29		12-29-80	
109S	W-273			1.17, 1.34		4-02-81	
109D		S-18		24		11-06-80	39' to 40'
109D		S-19		10		11-06-80	46' to 47'
109D	W-93			32.7, 33.5		11-14-80	
109D	W-145			8.72		12-10-80	
109D	W-203			6.22		12-29-80	
109D	W-274			12.1		4-02-81	
110S		S-14		<1		10-28-80	27.5' to 28'
110S	W-41			30.8		10-28-80	Inside HS at 28'
110S	W-42			120		10-28-80	
110S	W-62			98.1		10-31-80	
110S	W-81			128		11-07-80	
110S	W-92			141		11-14-80	
110S	W-158			141		12-11-80	
110S	W-269			55.2		4-01-81	

Water samples were taken inside well except where noted otherwise. Soil samples were taken by Split Spoon method.